

Research Article

The challenge of attaining conservation outcomes in a complex system: Agency personnel's and academic researchers' perspectives on the wicked problem of the exotic pet trade

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Abstract

The exotic pet trade is a wicked problem involving economic, social, political, ethical, and environmental dimensions, which cannot be resolved using conventional management strategies that are informed by restricted expertise. In 2023, we surveyed 26 government agency personnel and 57 academic researchers in the United States who focus on the risks of the exotic pet trade to ascertain how experts characterize the wicked problem of the exotic pet trade and their support for conventional versus collaborative management of the trade. Both academic and agency respondents framed the ecological risks associated with the exotic pet trade similarly, expressing greatest concern about species invasions and pathogen transmission to native species. Respondents exhibited low levels of trust in stakeholders in the exotic pet trade, considering it likely that all stakeholders (except the commercial industry) would fail to comply with pet trade regulations. Agency respondents tended to agree that current regulations have been effective in mitigating invasion risks while academic respondents disagreed that current regulations adequately mitigate the invasion and disease risks of the pet trade or overexploitation of species. Agency respondents were more likely to agree that regulations are enforceable. All respondents were supportive of additional federal regulations of the exotic pet trade. Our findings are consistent with the argument that wicked problems are perpetuated because managers and scientists default to conventional cause-effect problem statements and top-down management approaches that focus on management structure and execution. Transitioning from top-down regulatory approaches to collaborative decision making, in which agencies, scientists, and exotic pet trade stakeholders work together to resolve the wicked problem of the exotic pet trade, would build trust and allow for flexible, adaptive management of the trade.

Key words: Collaborative management, disease risk, invasion risk, management, policy, regulation, structured decision-making



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Introduction

Current conservation conflicts are typically wicked problems, which cannot be resolved using conventional management actions (Game et al. 2014; Mason et al. 2018). In their seminal paper, Rittel and Webber (1973) coined the term 'wicked problem' when they argued that policy problems are not mathematical problems

that can be efficiently resolved using scientific methods based on Newtonian mechanistic physics (which assumes that the universe is predictable, controllable, and law-abiding). Rather, conservation conflicts are complex, multifaceted issues with no clear solutions due to their interconnectedness, ambiguity, and diverse stakeholder involvement (Adams et al. 2019; Cosens et al. 2020). According to Rittel and Webber (1973), scientists and agencies fail to attain desirable, socially acceptable outcomes because they adopt an engineering approach in which scientific knowledge and models are applied to problems without first critically defining and locating problems. Scientists and agencies thus fail to distinguish between observed and desired conditions, assess the true causes of conflicts, or acknowledge that actions within complex socio-ecological systems may generate more severe problems (Rittel and Webber 1973; Game et al. 2014; Mason et al. 2018). The result is that the public and stakeholders lose trust in scientists and managers, who do not account for diverse and competing interests and world views, unintended and irreversible consequences of policy actions, and inequities (Rittel and Webber 1973; Game et al. 2014; Mason et al. 2018).

The exotic pet trade is indeed a wicked problem. Trade in exotic pets is a key driver of global environmental change (Robinson et al. 2015; Auliya et al. 2016b), contributing to invasion and disease risks, overexploitation of species, extinction of imperiled species, ecological disruptions, and biodiversity loss (Brown 2006; Hulme 2015). However, the exotic pet trade also involves social, economic, political, and ethical dimensions (Sinclair et al. 2021), intersecting with issues of animal welfare, public health risks (e.g., zoonotic diseases), economic well-being, cultural practices, competing stakeholder interests, and power inequities (Smith et al. 2012; Bush et al. 2014; Lockwood et al. 2019; Marra 2019). In defining the problem of the exotic pet trade, scientists and managers must account for ecosystem impacts, the welfare of traded animals (Pasmans et al. 2017; Warwick et al. 2018), legal frameworks (Pratt et al. 2024), social, psychological, and economic drivers of the pet trade (Hausmann et al. 2023; Pienaar and Sturgeon 2024), and different spatial scales at which impacts of the trade are manifest (Sinclair et al. 2021). Unfortunately, growing social and political conflicts pertaining to the exotic pet trade clearly demonstrate that conventional management strategies have failed to resolve the problems posed by the trade (Episcopio-Sturgeon and Pienaar 2019). We focus on the wicked problem of the exotic pet trade in the United States of America (US). The US contains the largest volume and most diverse array of exotic pets globally (Stringham et al. 2021) but inconsistent and incomplete regulations pertaining to the exotic pet trade have failed to mitigate the risks posed by the trade (Burgos-Rodríguez & Burgiel 2020; Pratt et al. 2024).

When considering the exotic pet trade, researchers have largely analyzed the ecological consequences of introducing non-native species into new environments (Brown 2006; Auliya et al. 2016a; Lockwood et al. 2019; Gippet and Bertelsmeier 2021), and the welfare of traded animals, specifically transportation, housing, and the psychological and physical well-being of exotic pets (Baker et al. 2013; Warwick et al. 2016; Whitehead 2016; Toland et al. 2020). Government agencies and NGOs, on the other hand, have typically focused on regulations to control and manage the trade, aiming to curb illegal trafficking and regulate ownership (Baker et al. 2013; Pratt et al. 2024). Agencies and NGOs have also focused on outreach efforts designed to educate the public about the ethical and ecological implications of the exotic pet trade and to reduce demand for and release of exotic

pets. However, these efforts have been undermined by unintended consequences (Levin et al. 2012), resistance by stakeholders with vested interests or conflicting world views (Waddock and Lozano 2013), changing societal values, technological advancements that make current efforts outdated, and increased online commerce (Bammer 2005; Oppenheimer 2011; Bertuol-Garcia et al. 2018). Management of the exotic pet trade has been further complicated by lack of comprehensive data on the number and species of exotic pets in the trade (Rhyne et al. 2012; Sinclair et al. 2021), limited agency resources and personnel to monitor and enforce written policies (Reeve 2006; Fonseca et al. 2021), jurisdictional barriers to interagency management of the exotic pet trade, and inconsistent regulations pertaining to the exotic pet trade (Pratt et al. 2024).

Despite clear evidence that the exotic pet trade is a wicked problem, managers and scientists may be resistant to pivoting from conventional “best practice” management approaches that are designed to address single objectives in simple environments to developing strategies that address complexity (Game et al. 2014; Mason et al. 2018). “Best practice” actions that treat the exotic pet trade as a conventional cause-effect problem are far easier to implement because they replicate past, known practices and are suited to current institutional structures (Game et al. 2014). Conventional management involves top-down decision making, which is informed by restricted expertise, and fails to predict the potential impacts of management decisions on complex, dynamic environments (Game et al. 2014; McEachran et al. 2024; Cook et al. 2025). Although agencies claim to engage in adaptive management, management actions are typically focused on feedback controls because this reduces cognitive effort and resources needed for planning by allowing managers to apply simple mental models and rules of thumb (Game et al. 2014; McEachran et al. 2024). Rather than investing in understanding complex systems, managers focus on management structure and execution (Game et al. 2014), which may result in a ‘Type III error’ (finding a good solution to the wrong problem; Mitroff and Silvers 2010).

To help inform efforts to improve the management of the exotic pet trade in the US, we conducted an initial, exploratory investigation of how experts characterize the wicked problem of the exotic pet trade and their support for conventional versus collaborative management of the trade. We focused on invasion scientists who work for state and federal government agencies and academic institutions in the US because these individuals comprise the experts who typically inform policy and management efforts. Although the US Fish and Wildlife Service (USFWS) is the primary federal agency that enforces laws related to the exotic pet trade, states retain most regulatory authority over the trade (Pratt et al. 2024). State agencies use a mix of prohibited lists of species that may not be legally imported or owned (commonly referred to in the wildlife trade literature as ‘blacklists’) and lists of approved species for import and ownership (commonly referred to as ‘whitelists’; Hulme 2015; Bowen 2021) to regulate the pet trade within their state (Pratt et al. 2024). We examined agency personnel and academic researchers’ 1) perceptions of the risks and benefits posed by the exotic pet trade, 2) knowledge of current exotic pet regulations, 3) perceptions of the effectiveness of current regulations in mitigating risks, 4) opinions on the constraints to effective regulation of the trade, and 5) support for additional management of the exotic pet trade. We further examined whether experts believed that state agencies’ risk perceptions pertaining to the exotic pet trade match their personal risk perceptions.

Methods

Questionnaire design

We designed an online questionnaire to be administered to individuals specializing in invasion science and working for universities or state and federal wildlife or agricultural agencies. In addition to asking respondents their gender, age, and education level, we collected information about their professional experience, the state they work in, the agency or university they work for, and their job titles.

Perceived risks and benefits associated with the exotic pet trade

Before asking agency personnel about the risks that the exotic pet trade poses, we asked them to indicate the exotic pets (hereafter, species) over which their agency has regulatory authority ('birds', 'rodents', 'large carnivores', 'primates', 'other mammals', 'reptiles', 'amphibians', 'fish', 'mollusks', 'crustaceans', 'insects/arachnids'). Agency personnel who stated that their agency had no regulatory authority over exotic pets, or they did not know which exotic pets their agency regulated, were asked to identify which species they thought posed risks within their state. We asked academic researchers which species they study or consider risks within their state.

For each of the species that respondents selected, we asked how concerned they were that trade in these species as pets would result in 1) transmission of pathogens to humans, native animals, and agricultural industries, 2) species invasions, 3) unregulated harvest of wild populations of species, and 4) extinction of native species ('not at all concerned', 'slightly concerned', 'moderately concerned', 'concerned', or 'very concerned'). We also asked respondents to indicate their state agency's concern pertaining to trade in these species as exotic pets ('N/A; I do not know' response provided for respondents who were uncertain about their agency's regulatory authority over the exotic pet trade). Finally, all respondents indicated their personal and agency concern about whether exotic pet owners would voluntarily comply with exotic pet regulations.

As a further measure of risk perceptions, we asked respondents the likelihood that the commercial pet industry (large wholesale and retail enterprises that breed or sell exotic pets at high volumes, and may be part of a national chain of stores), the hobbyist industry (smaller home-based enterprises that breed or sell pets at low volumes, and specialize in specific taxa or species of pets), the exposition industry (enterprises that participate in events where pet breeders and sellers gather to exhibit and sell pets, e.g. Repticon, <https://repticon.com/>), and exotic pet owners (who do not breed, sell, or exhibit exotic pets) would comply with existing exotic pet regulations, or engage in illegal behavior pertaining to the trade and release of pets ('very unlikely', 'unlikely', 'neither likely nor unlikely', 'likely', 'very likely', 'I do not know/I do not have any experience with this group'). We also asked respondents how likely they thought it was that these different stakeholders in the pet trade would contribute to invasion risks, pathogen transmission risks, overexploitation of wild populations, and species extinctions in the US ('not at all likely' to 'extremely likely'). Respondents indicated what percentage of the animals traded by the commercial, hobbyist, and exposition industries they thought were healthy (i.e., free of pathogens). Finally, respondents stated how often they thought exotic pet owners deliberately released their pets into the wild ('never', 'rarely', 'sometimes', 'often').

We assessed respondents' perceptions of the benefits of the exotic pet trade by asking them whether they agreed that the exotic pet trade is beneficial to the economy, and the exotic pet trade helps conserve endangered species ('strongly disagree', 'disagree', 'neither agree nor disagree', 'agree', 'strongly agree').

Knowledge of exotic pet regulations

We assessed all respondents' knowledge of current exotic pet regulations in their state (I know 'all', 'some', or 'none' of the exotic pet regulations in my state). To measure agency respondents' knowledge of their agency's regulatory authority over the exotic pet trade, we asked if their agency had jurisdiction over the exotic pet trade ('yes, all exotic pets', 'yes, some exotic pets', 'maybe/I am not sure', and 'no'), as well as what type of regulation their agency uses ('whitelists', 'blacklists', 'both whitelists and blacklists', 'neither'). We further asked if respondents were familiar with proposed amendments to the federal Lacey Act ('yes', 'no', 'I do not know'). Recently, to promote increased enforcement of regulations for the exotic pet trade, the House of Representatives proposed HR 4521 (i.e., America COMPETES Act or Lacey Act Amendments; hereafter, Lacey Act Amendments). Three fundamental changes to the importation of species into the US and interstate trade of animals were proposed, namely: 1) the creation of a list of approved species that can be imported into the US, where any animal not listed is treated as an injurious species by default and banned from importation; 2) changes to the Lacey Act shipment clause to ban the interstate transport of species listed as injurious; and 3) conferral of new emergency powers that would provide the USFWS with the ability to prohibit the importation of injurious species for up to three years. If passed, the Lacey Act amendments would reduce inconsistencies in exotic pet trade regulations. Finally, we asked agency respondents to list other agencies (if any) with jurisdiction over the exotic pet trade in their state.

Perceptions of current exotic pet regulations

All respondents indicated how effective they thought exotic pet regulations in their state (as currently written) were in preventing invasion risks, disease risks, overexploitation of species, and species extinction ('not at all effective', 'slightly effective', 'moderately effective', 'effective', 'very effective', 'I do not know'). To obtain further insights, we asked respondents if, to the best of their knowledge, current regulations are being enforced, or can realistically be enforced in their state. Respondents also indicated whether they agreed that 1) jurisdictional barriers between agencies, 2) lack of agency funding and, 3) lack of trained agency staff prevents effective regulation of the pet trade, and that 4) agency staff have difficulty in identifying different species ('strongly disagree' to 'strongly agree'). As a final measure of respondents' perceptions of the effectiveness of regulations, we asked whether they agreed that current regulations adequately mitigate invasion risks, disease risks, overexploitation of species, and extinction risks, and that current regulations are enforceable ('strongly disagree' to 'strongly agree').

Support for altered regulation and management of the exotic pet trade

Respondents indicated whether they supported trade in native and non-native animals as pets within their state ('strongly oppose', 'somewhat oppose', 'neither oppose nor support', 'somewhat support', 'strongly support'). We assessed

respondents' support for proposed exotic pet regulations by asking them whether they support the Lacey Act Amendments. Respondents also stated whether they thought collaboration between their state agency and the commercial, hobbyist, and exposition industries (i.e., co-management of the exotic pet trade) would be 1) likely to occur ('not at all' to 'extremely' likely), and 2) effective in improving compliance with exotic pet regulations ('not at all' to 'very' effective). Finally, respondents indicated whether the risks associated with the exotic pet trade would be effectively mitigated by implementing 1) a three-day waiting period before a potential owner can collect a pet from the store, 2) allowing owners to return their animal to the pet store at no penalty to them, 3) tagging animals through skin or pit tags before they can be taken home so owners of released pets can be identified, and 4) adding a sales tax to exotic pet purchases to help fund agency efforts to regulate the pet trade.

Pretesting and ethics approval

We pretested this survey with four human dimensions, strategic communication, and invasion ecology experts. The Institutional Review Board at the University of Georgia reviewed the final survey and determined it was exempt (ID: PROJECT00006638).

Data collection

Data collection occurred from January to April 2023. We compiled a list of publicly available email addresses for adults (aged ≥ 18 years) who engaged in invasion science and worked for universities or state or federal wildlife or agricultural agencies across the US. We targeted these experts because they are most likely to inform or implement management actions, based on their understanding of 1) which species pose invasion risks within the state in which they reside, 2) what measures (e.g., trade regulations) are needed to mitigate these invasion risks, and 3) how state agencies have responded to invasion risks. We sent an initial email invitation to participate in our study, followed by ≤ 9 reminders (~ 2 /month) if participants had not completed the survey. Once participants completed the survey, they did not receive reminders. Individuals who elected not to participate in our study received no follow-up emails.

Data analysis

We performed all statistical analyses with SPSS version 28.0 and R version 4.0.4. We used Kruskal Wallis H tests to test for differences in 1) survey responses by agency personnel and academic researchers and 2) responses pertaining to personal versus agency risk perceptions.

Results

We received 26 agency personnel responses from 99 email-delivered surveys ($\sim 26\%$ response rate), with 20 responses from state agency representatives and six from federal agency representatives. We received 57 academic researcher responses from 146 email-delivered surveys ($\sim 39\%$ response rate).

Most respondents (62.7%) identified as male (Table 1). The median age category for respondents was 45–54 years, and the median education level was an advanced degree. Most academic respondents had ≥ 11 years of professional experience in invasion science, with job titles including associate professor, unit leader, and research biologist/ecologist. Most agency respondents had ≥ 11 years of professional experience, and had worked 3–5 years in their current position, with job titles including conservation biologist, division director, program coordinator, and research manager.

Perceived risks and benefits associated with the exotic pet trade

Agency respondents most frequently reported that small mammals (excluding rodents, 61.5%), reptiles (53.8%), amphibians (50.0%), birds (50.0%), and fish (50.0%) were the species over which their agency had regulatory authority (Suppl. material 1: table S1). Academic respondents most frequently reported that they researched or were concerned about risks posed by fish (63.2%) and mollusks (54.4%). Agency and academic respondents expressed similar levels of concern pertaining to species invasions, pathogen transmission to native species, agricultural industries, and humans, unregulated harvest, and extinction of wild populations owing to the exotic pet trade (Fig. 1; Suppl. material 1: tables S2–S7). However, agency and academic respondents differed in their perceptions of the state agency’s concern about trade in crustaceans resulting in the extinction of wild species ($H(1)=3.888$, $p = 0.049$).

Table 1. Demographic characteristics and professional experience of survey respondents, January-April 2023 (n = 83).

	Agency (n = 26)		Academic (n = 57)		Total (n = 83)	
	Number	%	Number	%	Number	%
Gender						
Male	15	57.7	37	64.9	52	62.7
Female	10	38.5	20	35.1	30	36.1
Prefer not to say	1	3.8	0	0.0	1	1.2
Age						
25–34 years	1	3.8	4	7.0	5	6.0
35–44 years	9	34.6	17	29.8	26	31.3
45–54 years	11	42.3	16	28.1	27	32.5
55–64 years	5	19.2	14	24.6	19	22.9
≥65 years	0	0.0	6	10.5	6	7.2
Education						
Bachelor’s degree	7	26.9	0	0.0	7	8.4
Advanced degree	19	73.1	57	100.0	76	91.6
Length of employment						
< 1 year	0	0.0	1	1.8	1	1.2
1, 2 years	0	0.0	0	0.0	0	0.0
3–5 years	2	7.7	4	7.0	6	7.2
6–10 years	6	23.1	10	17.5	16	19.3
≥11 years	18	69.2	42	73.7	60	72.3
Time in current position						
< 1 year	3	11.5	-	-	-	-
1, 2 years	4	15.4	-	-	-	-
3–5 years	7	26.9	-	-	-	-
6–10 years	6	23.1	-	-	-	-
≥11 years	6	23.1	-	-	-	-

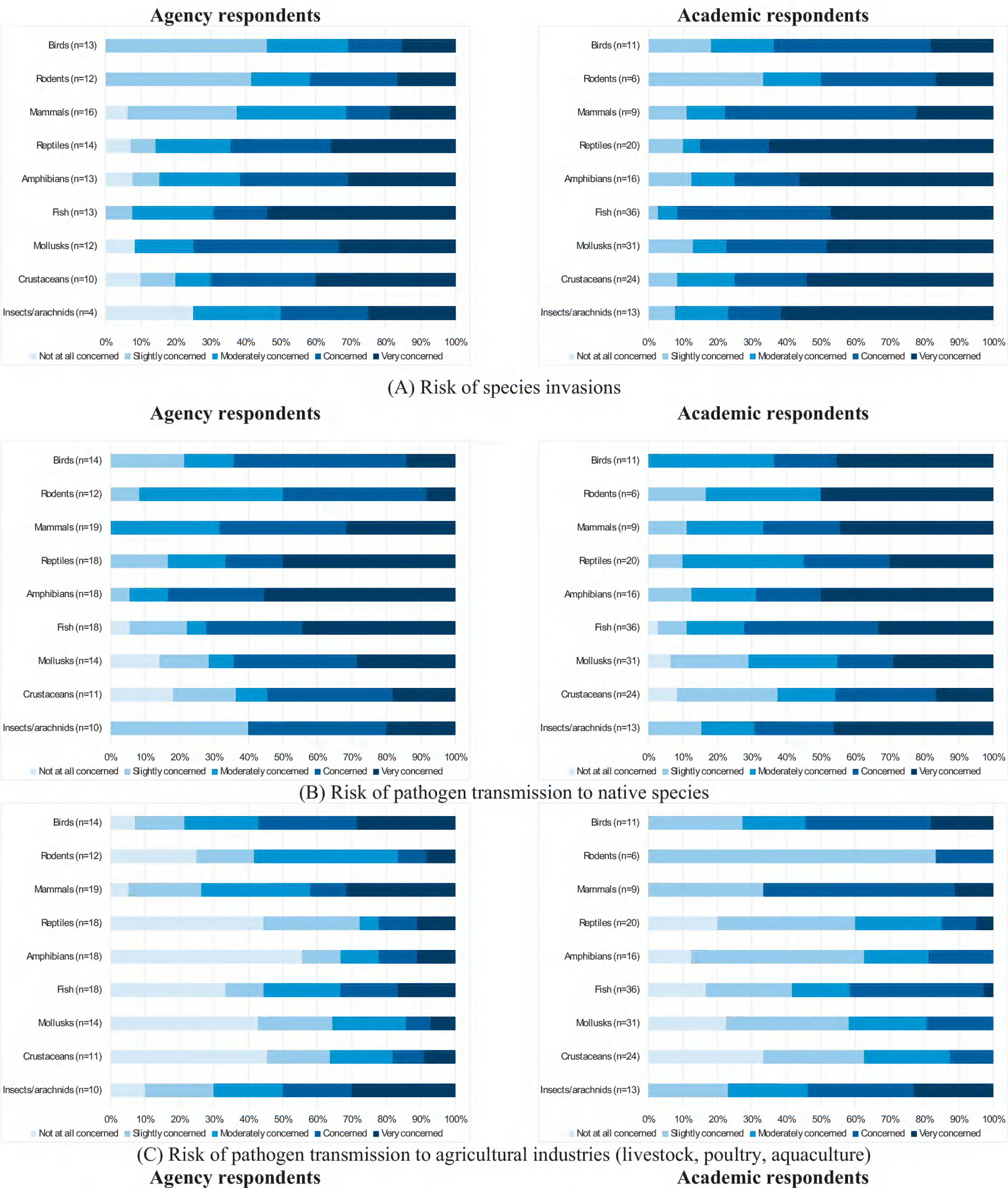


Figure 1. Respondents’ risk sensitivity to threats posed by the exotic pet trade. Respondents answered the question: “How concerned are you about the possibility that trade in the following animals (as pets) will result in **A** species invasions **B** pathogen transmission to native species **C** pathogen transmission to agricultural industries (livestock, poultry, aquaculture), and **D** pathogen transmission to humans in your state **E** unregulated harvest of wild species, and **F** extinction of wild species within the US?” ‘Mammals’ exclude rodents, primates, and large carnivores.

Agency respondents’ personal concern about the risks posed by the exotic pet trade was similar to their perceptions of how concerned agencies were about these risks. Academic respondents’ personal concern about pathogen transmission risks and the risks of unregulated harvest of wild populations

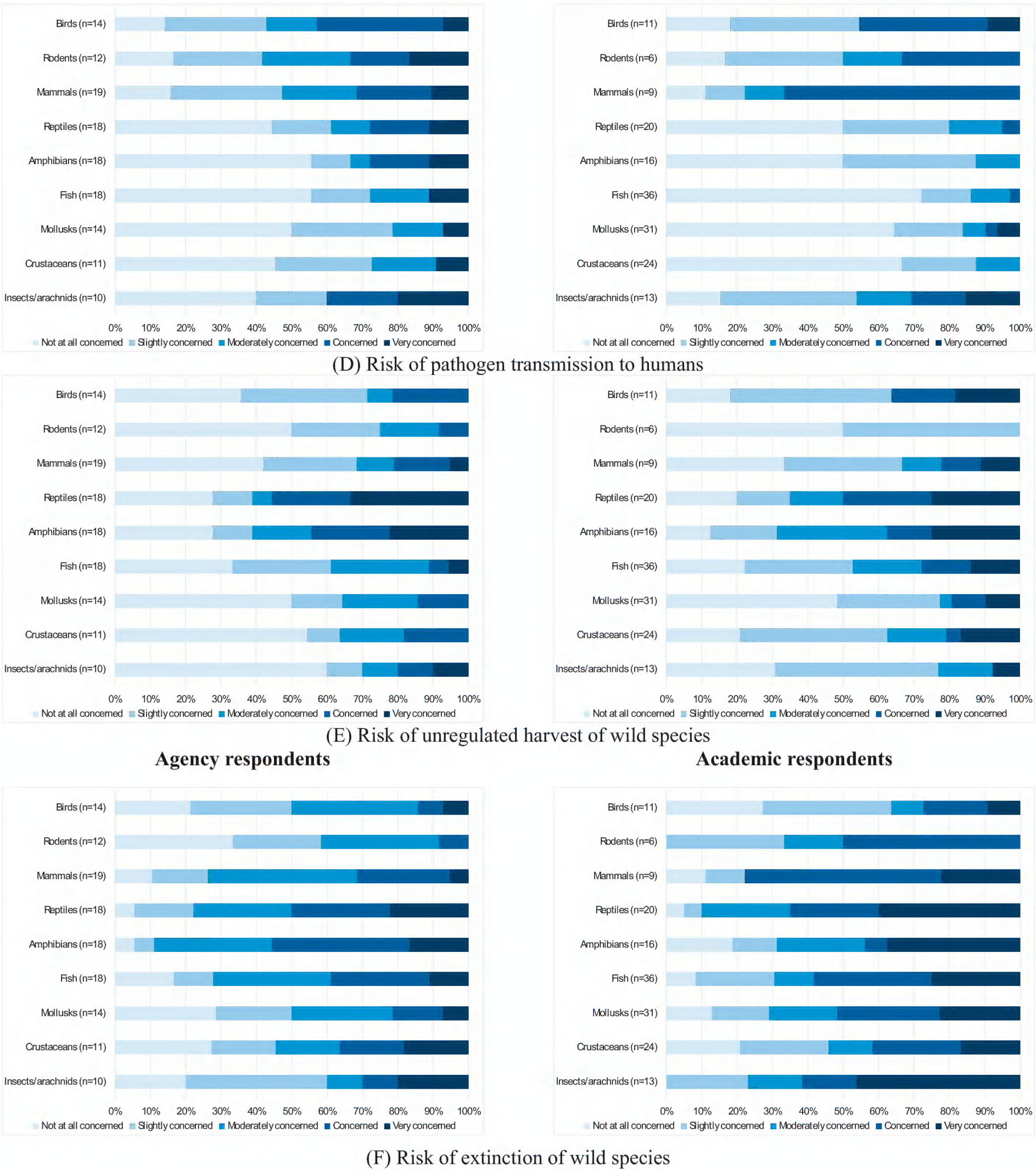


Figure 1. Continued.

was also similar to perceived agency concern about these risks. However, academic respondents stated that, in their opinion, they were more concerned than agencies were that trade in pet amphibians and reptiles (median='very concerned') would result in species invasions (amphibians: median='moderately concerned'; $H(1)=5.847$, $p = 0.016$; reptiles: median='concerned'; $H(1)=5.168$, $p = 0.023$; Fig. 2). Similarly, academic respondents stated that they were more concerned (median='concerned') than agencies (median='moderately concerned') that trade in pet reptiles would result in extinction of wild populations ($H(1)=4.969$, $p = 0.026$).

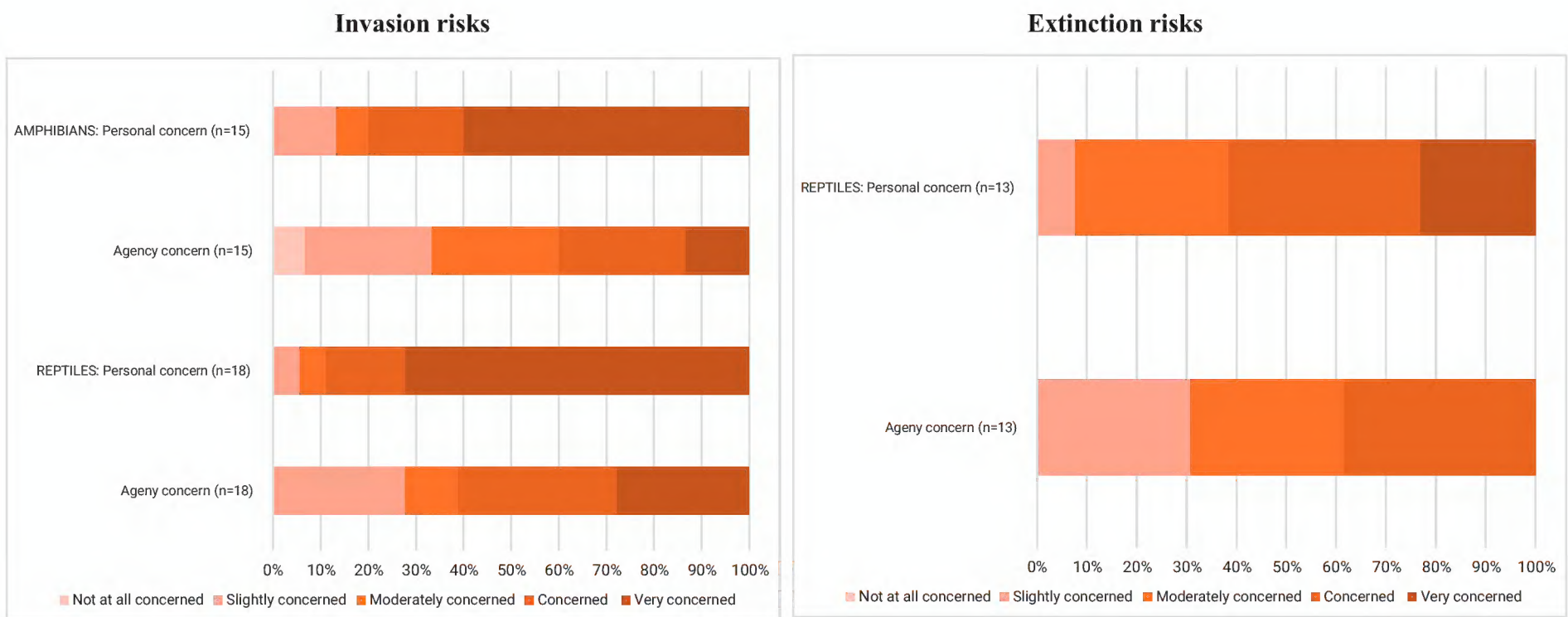


Figure 2. Academic respondents' personal concern about the invasion and extinction risks associated with the exotic pet trade, and their perceptions of state agencies' concern about these risks. Respondents who stated that they did not know how concerned the state agency was about these risks are excluded from the figure.

On average, agency and academic respondents were concerned about exotic pet owners voluntarily complying with pet trade regulations (Suppl. material 1: table S8). Agency respondents indicated that their concern about pet owners complying with regulations was similar to the state agency's perceived concern about compliance. In contrast, academic respondents argued that their concern about pet owners complying with regulations exceeded agency concern ($H(1)=8.588$, $p = 0.003$).

Academic and agency respondents expressed similar opinions about which pet trade stakeholders would comply with current regulations and illegally trade and release exotic pets. They considered that hobbyist breeders and sellers, the exposition industry, and exotic pet owners were unlikely to comply with regulations and were likely to illegally trade and release exotic pets, whereas the commercial industry would be likely to comply with regulations and unlikely to engage in illegal behaviors (Suppl. material 1: fig. S1, tables S9, S10). Agency and academic respondents also expressed similar opinions about the probability that these four stakeholder groups would contribute to invasion risks (mean responses for agency respondents ranged from 6.2–7.0, mean responses for academic respondents ranged from 6.9–8.0 where 'not at all likely'=0 and 'extremely likely'=10; Suppl. material 1: fig. S2), pathogen risks (agency respondents: $6.5 \leq \text{mean} \leq 7.0$, academic respondents: $6.1 \leq \text{mean} \leq 7.1$; Suppl. material 1: fig. S3) and species extinctions in the US (agency respondents: $4.1 \leq \text{mean} \leq 4.6$, academic respondents: $4.3 \leq \text{mean} \leq 4.9$; Suppl. material 1: fig. S4, Table S11). However, academic respondents thought the hobbyist industry was more likely to contribute to the overexploitation of wildlife in the US (6.3 ± 2.7) than agency respondents (4.8 ± 2.6 ; $t = -2.454$, $p = 0.009$; $H(1)=5.873$, $p = 0.015$; Suppl. material 1: fig. S5). On average, respondents thought that 57.8% of animals traded by the commercial industry were healthy, 55.0% of animals traded by the hobbyist industry were healthy, and 50.2% of animals traded by the exposition industry were healthy (Suppl. material 1: table S12). Most respondents (90.4%) thought exotic pet owners deliberately release their exotic pets into the wild at least sometimes (Suppl. material 1: table S13). Most respondents also disagreed that the exotic pet trade benefits the economy (54.2%) or helps to conserve endangered species (88.0%; Suppl. material 1: table S14).

Knowledge of exotic pet regulations

In total, 10 agency respondents (38.5%) and 7 academic respondents (12.3%) were aware of all exotic pet regulations in their state (42.3% of agency respondents and 68.4% of academic respondents were aware of some regulations). The majority of respondents (65.4% of agency respondents, 66.7% of academic respondents) were unaware of the Lacey Act amendments prior to the survey. Regarding regulatory approaches, 33.3% of agency respondents indicated that their agency uses lists of prohibited species, while 4.8% reported using lists of species that may be legally owned and traded. Additionally, 33.3% of agency respondents stated that their agency employs both types of lists (prohibited and authorized species), 23.8% reported using neither type of list, and 4.8% were uncertain or unaware of their agency’s regulatory approach. Finally, 81.0% of agency respondents reported shared jurisdiction over the exotic pet trade, primarily between the state agricultural and wildlife agencies.

Perceptions of current exotic pet regulations

On average, agency respondents considered current exotic pet regulations in their state to be moderately effective in preventing disease risks, invasion risks, overexploitation of species, and extinction, whereas academic respondents considered regulations to be slightly effective (Suppl. material 1: fig. S6, table S15). Agency respondents were more likely to agree that current regulations adequately mitigate invasion risks (median=‘somewhat agree’) than academic respondents (median=‘somewhat disagree’; $H(1)=4.884$, $p = 0.027$; Fig. 3, Suppl. material 1: table S16). Agency respondents were also more likely to agree that current regulations adequately mitigate species overexploitation (median=‘neither agree nor disagree’) than academic respondents (median=‘somewhat disagree’; $H(1)=6.552$, $p = 0.010$).

Respondents most frequently stated that current regulations are enforced sometimes (61.9% of agency respondents, 45.7% of academic respondents; Suppl. material 1: table S17). Only seven agency respondents (33.3%) and 11 academic respondents (23.9%) thought regulations could realistically be

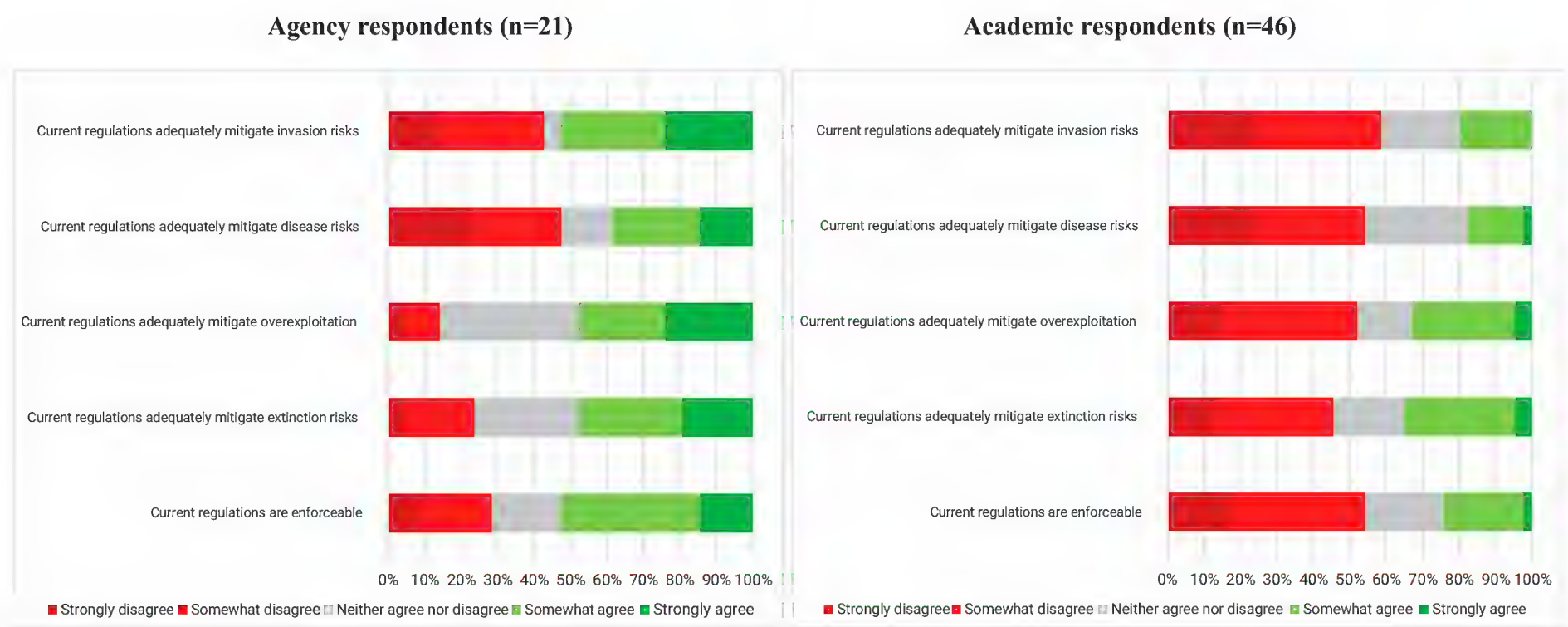


Figure 3. Respondents’ agreement with statements about exotic pet regulations in their state.

enforced in their state. Agency personnel were more likely to agree that current regulations are enforceable (median='somewhat agree') than academic researchers (median='somewhat disagree'; $H(1)=5.468$, $p = 0.019$). Respondents most strongly agreed that lack of agency funding prevents effective regulation of the exotic pet trade (Fig. 4, Suppl. material 1: table S18). On average, respondents neither agreed nor disagreed that agency staff have difficulty in identifying different species in the pet trade.

Support for altered regulation and management of the exotic pet trade

On average, both agency and academic respondents somewhat opposed the sale of non-native animals as pets in the US (Suppl. material 1: table S19). However, agency respondents were more opposed to the sale of native species as pets in the US than academic respondents ($H(1)=12.951$, $p < 0.001$). Agency and academic respondents did not differ in their support for proposed Lacey Act amendments (Table 2). Most respondents supported the creation of a whitelist of approved species that can be imported, changing the Lacey Act shipment clause to ban the interstate transport of species listed as injurious, and new emergency powers allowing the USFWS to prohibit the importation of injurious species for up to three years.

Academic respondents considered it more likely that state wildlife agencies and the commercial industry would collaborate to manage the exotic pet trade (5.2 ± 2.6 ; range: 0 to 10) than agency respondents (3.6 ± 3.3 ; range 0 to 10; $H(1)=5.474$, $p = 0.019$). Agency and academic respondents did not differ in their assessment of the likelihood that the hobbyist (agency respondents: 3.6 ± 2.8 ; academic respondents: 3.9 ± 2.1) and exposition industries (agency respondents: 3.2 ± 2.8 ; academic respondents: 3.6 ± 2.2) would collaborate with the state wildlife agency to manage the pet trade.

On average, respondents indicated that collaboration between the state agency and the hobbyist and exposition industries would be moderately effective at enforcing pet trade regulations (Fig. 5, Suppl. material 1: table S20). However, academic respondents believed that co-management of the pet trade with the

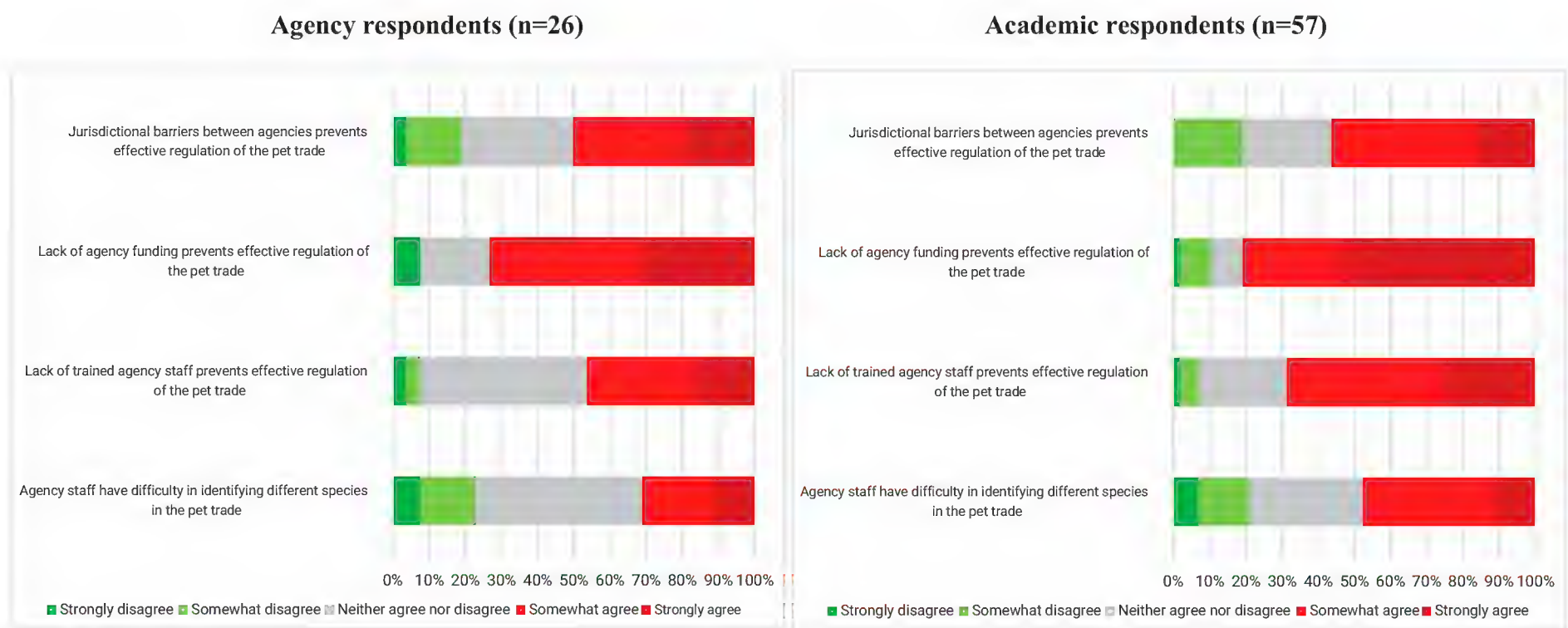


Figure 4. Respondents' opinions on barriers to effective regulation of the exotic pet trade. Note: We found no statistical difference in the distribution of responses across agency and academic respondents.

Table 2. Respondents’ support for proposed Lacey Act amendments, January-April 2023 (n = 83).

	Median	N	Strongly oppose	Somewhat oppose	Neither support nor oppose	Somewhat support	Strongly support
Agency respondents:							
Create a list of approved species that can be imported, where any animal not listed is treated as an injurious species by default and banned from importation into the US.	Somewhat support	26	0 (0.0%)	4 (15.4%)	4 (15.4%)	10 (38.5%)	8 (30.8%)
Change the Lacey Act shipment clause to ban the interstate transport of species listed as injurious.	Somewhat support	26	0 (0.0%)	0 (0.0%)	2 (7.7%)	13 (50.0%)	11 (42.3%)
Establish new emergency powers that would provide the US Fish and Wildlife Service (USFWS) with the ability to prohibit the importation of injurious species for up to three years.	Strongly support	26	0 (0.0%)	0 (0.0%)	3 (11.5%)	8 (30.8%)	15 (57.7%)
Academic respondents:							
Create a list of approved species that can be imported, where any animal not listed is treated as an injurious species by default and banned from importation into the US.	Somewhat support	57	2 (3.5%)	1 (1.8%)	10 (17.5%)	19 (33.3%)	25 (43.9%)
Change the Lacey Act shipment clause to ban the interstate transport of species listed as injurious.	Strongly support	57	2 (3.5%)	0 (0.0%)	3 (5.3%)	17 (29.8%)	35 (61.4%)
Establish new emergency powers that would provide the US Fish and Wildlife Service (USFWS) with the ability to prohibit the importation of injurious species for up to three years.	Strongly support	57	1 (1.8%)	0 (0.0%)	5 (8.8%)	17 (29.8%)	34 (59.7%)

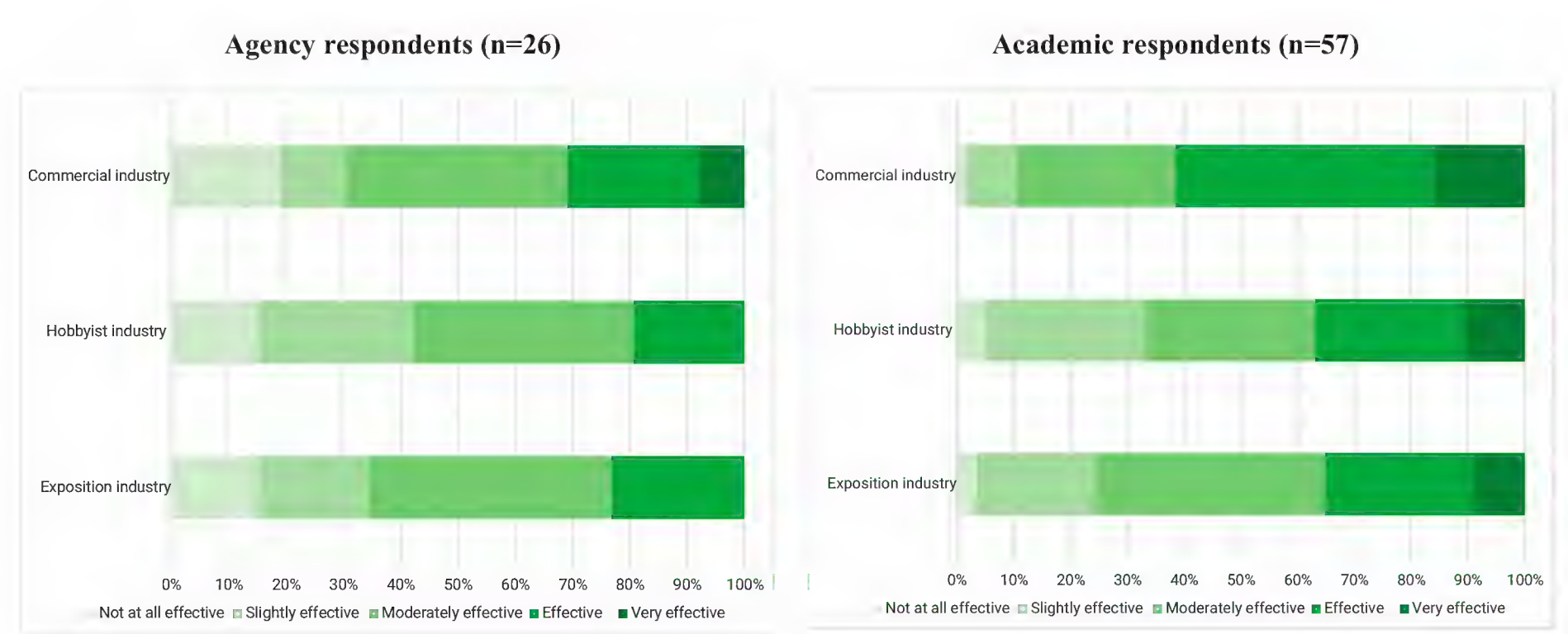


Figure 5. Distribution of responses to the question, “How effective would a collaboration between your state wildlife agency and the following groups be at helping enforce pet trade regulations?”

commercial industry would be more effective at enforcing pet trade regulations (median=‘effective’) than agency respondents (median=‘moderately effective’; $H(1)=7.908$, $p = 0.005$). Academic respondents also believed that adding a sales tax to exotic pet purchases to help fund agencies responsible for regulating the pet industry would be more effective at reducing the risks associated with the exotic pet trade (median = ‘effective’) than agency respondents (median = 2.5 where ‘slightly effective’ = 2 and ‘moderately effective’ = 3; $H(1) = 15.453$, $p < 0.001$; Fig. 6, Suppl. material 1: table S21). Agency and academic respondents did not differ in their agreement on the effectiveness of a three-day waiting period for pet purchases (median=‘slightly effective’), skin or pit tags for exotic pets (median=‘moderately effective’), and allowing owners to return unwanted pets (median for agency respondents=‘moderately effective’, median for academic respondents=‘effective’) in mitigating the risks of the exotic pet trade.

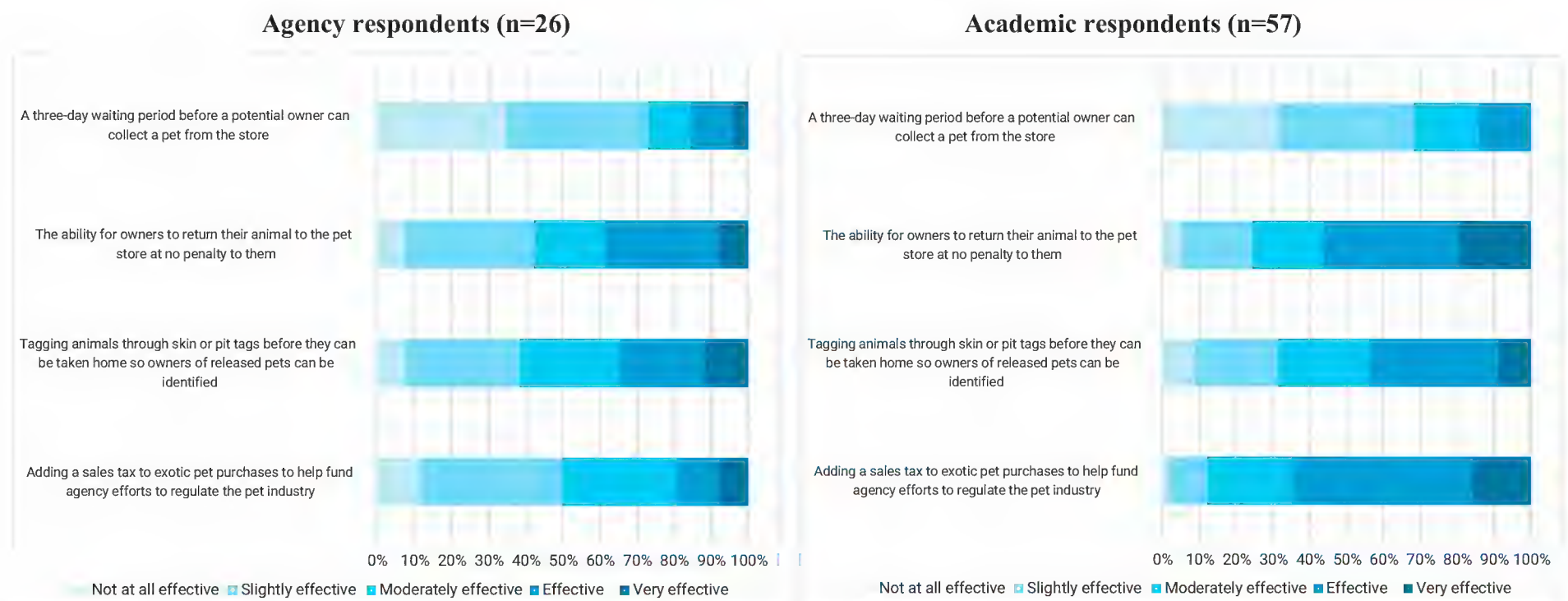


Figure 6. Distribution of responses to the question, “Assuming that the following management actions could be implemented in your state, please indicate how effective they would be at reducing the risks associated with the exotic pet trade”.

Discussion

The exotic pet trade presents a wicked problem, where researchers play a pivotal role in understanding the potential risks of the trade and government agencies play a pivotal role in managing these risks. We recognize that not all research scientists focus on applied research that is intended to inform management and decision-making. We specifically targeted managers and academics who focus on invasion science within the larger fields of wildlife, fisheries, and agriculture because most authority for managing the exotic pet trade lies with wildlife, fisheries, and natural resource agencies (Pratt et al. 2024), whose personnel are likely to be trained in biological and veterinary sciences. As such, current and proposed management of the exotic pet trade in the US are largely informed by restricted expertise. Our findings are consistent with arguments that decision and governance impediments result in managers and scientists defaulting to conventional cause-effect problem statements and piecemeal management approaches, rather than collaborative solutions that would more effectively address the wicked problem of the exotic pet trade (Game et al. 2014; Mason et al. 2018; Cook et al. 2025).

There were logical inconsistencies in how invasion scientists at academic and government institutions in the US framed the wicked problem of the exotic pet trade, their evaluation of the effectiveness of current top-down management approaches, and their stated support for additional top-down regulation of the exotic pet trade. Agency and academic respondents often framed the ecological risks associated with the exotic pet trade similarly, disagreeing that the exotic pet trade helps to conserve endangered species, expressing greatest concern about species invasions and pathogen transmission to native species, and suggesting that over half of the animals in the exotic pet trade are not healthy. However, respondents were less concerned about pathogen transmission to humans and agricultural industries and unregulated harvest of species – which are important adverse consequences of the exotic pet trade. Agency respondents may have expressed less concern about zoonotic and livestock disease risks because existing agency mandates and directives undermine incentives for wildlife agencies to manage zoonotic and livestock pathogen risks, which are largely under the authority of agricultural and human health agencies (Cook et al. 2025). Both agency and academic respondents agreed that lack of agency funding prevents

effective regulation of the pet trade, which is consistent with arguments that limited agency resources and capacity hinder management (Cook et al. 2025). Agency respondents also acknowledged that their agencies only regulate a subset of the species in the exotic pet trade, which limits their authority to mitigate exotic pet trade risks (Pratt et al. 2024; Cook et al. 2025). Yet, agency respondents tended to agree that current regulations are enforceable and have been 'moderately effective' or 'effective' in mitigating risks posed by the pet trade. This was inconsistent with most respondents' beliefs that exotic pet owners sometimes or often release their exotic pets into the wild, and that all stakeholders (except the commercial industry) are unlikely to comply with pet trade regulations and are likely to engage in illegal behavior pertaining to the trade and release of pets. Academic respondents demonstrated fewer logical inconsistencies, disagreeing that current regulations adequately mitigate the risks posed by the pet trade. Despite concerns about the trade in, and release of, pets that pose invasion and pathogen risks, respondents expressed doubts about implementing measures that would provide exotic pet owners with time to reconsider the purchase of a pet, the ability to return unwanted pets (academic respondents considered this to be more effective than agency respondents), identifying which owners release pets through skin or pit tags, and increased agency funding through the implementation of a sales tax on exotic pets (academic respondents considered this to be more effective than agency respondents). Rather, most respondents supported additional federal regulations in the form of the Lacey Act amendments – possibly because federal regulations would address inconsistencies in state regulations and would provide agency respondents with clear rules pertaining to management of the exotic pet trade (Pratt et al. 2024). However, it is not clear how federal regulations would address limited agency resources and personnel to monitor and enforce written policies (Reeve 2006; Fonseca et al. 2021).

Strong arguments can be made that multi-sector, collaborative governance is necessary to attain improved management of the exotic pet trade (Mason et al. 2018). Transitioning to co-management approaches, in which exotic pet trade stakeholders collaborate with scientists and government agencies to design and implement interventions, may result in increased trust between agencies, scientists, and stakeholders in the pet trade, and improved management of the exotic pet trade (Mason et al. 2018; Episcopio-Sturgeon and Pienaar 2019). Strategies from decision science and negotiation theory can be used to transition to collaborative governance of the exotic pet trade (Cook et al. 2025), even when experts have differing views and there is uncertainty about the likely effectiveness of different policies. Structured decision-making (SDM) is a formal values-based decision analytic framework and process that integrates social and ecological data to identify 1) clearly defined decision problems, 2) different objectives that reflect what different groups care about most, 3) alternative management actions, 4) barriers to decision-making (e.g., incomplete knowledge, risk, uncertainty, resource limitations, limited authority), and 5) tradeoffs among objectives (Runge et al. 2020). Agencies (managers), experts (scientists), and stakeholders (exotic pet trade) could engage in participatory SDM to identify possible interventions to mitigate the ecological and disease risks of the exotic pet trade while also considering the socio-psychological values and economic priorities of the trade.

The SDM process ensures that decision-making related to complex, contentious issues incorporates science and values in a transparent process that is robust to uncertainty (Runge et al. 2020). SDM uses data and expert opinion as the basis for predicting the likelihood that each alternative policy will fulfill the various desired objectives. Our study shows that experts differ in their assessments of how well

different interventions would achieve various objectives for exotic pet regulation. Differences in expert opinions about outcomes of interventions are a challenge for policymaking related to wicked problems. SDM is a particularly helpful tool for navigating that challenge. SDM explicitly incorporates the uncertainty that arises due to differences in expert opinion, tracking it through complex chains of cause-effect relationships, from intervention to expected outcomes. The likelihood of resulting predictions is adjusted to account for that uncertainty, thus offering a robust basis for decision-making even under uncertainty.

Importantly, SDM can build trust between agencies, scientists, and stakeholders (Robinson et al. 2016). This is a critical consideration in addressing the wicked problem of the exotic pet trade. Respondents' current lack of trust in pet trade stakeholders was manifest in their opinion that state agencies, hobbyist breeders and sellers, and exposition industries are unlikely to collaborate to manage the exotic pet trade, and that such collaboration would be moderately effective in enforcing regulations. However, agency respondents thought it was moderately likely that state agencies and the commercial industry would collaborate to manage the trade, and academic respondents thought collaboration between state agencies and the commercial industry would be effective at enforcing regulations. Engaging agency and academic researchers in decision-making processes that rigorously explore collaborative management alternatives could foster productive dialogue and reduce political and social conflicts between the exotic pet trade, scientists, and managers (Stout et al. 1999; Harris et al. 2010; Stern and Coleman 2015; Episcopio-Sturgeon and Pienaar 2019). Involving the exotic pet industry in collaborative management could generate a sense of ownership and responsibility, thereby encouraging industry stakeholders to adhere to regulations, voluntarily adopt best practices to mitigate the risks of the trade, and participate in conservation efforts.

Objectives identified through a multi-sector, multi-disciplinary SDM process could be used to identify possible management actions or interventions. For example, interventions may include changes to exotic pet regulations (Pratt et al. 2024), redistribution of resources to improve the capacity of agencies to respond to the risks posed by the exotic pet trade, education and communication campaigns that promote behavior change by exotic pet owners, and expanded adoption networks for unwanted exotic pets (Episcopio-Sturgeon and Pienaar 2019). Social scientists would play an important role in the SDM process by eliciting exotic pet trade participants' feedback and suggestions on different management objectives, a critical step to building trust between the exotic pet trade, scientists, and decision-makers (Robinson et al. 2016). Expert elicitation, empirical data, statistical and simulation models, and surveys of the exotic pet trade can be used to predict the consequences of different management actions in terms of invasion and disease risks, economic impacts, and support by the exotic pet trade (Robinson et al. 2016). Finally, the relative costs and impacts of different management actions can be determined, allowing participants to clearly see how each intervention is likely to satisfy each objective, and have transparent discussions about which interventions are preferable, given constraints and tradeoffs.

SDM related to the exotic pet trade should include experts in invasion science, public health (Can et al. 2019; van Roon et al. 2019), animal health, welfare, and transport (de Vos et al. 2017; Sutherland et al. 2021), social sciences (Robinson et al. 2016), strategic communication, and law, in order to identify management objectives with the potential to minimize the risks of the exotic pet trade while also securing the economic and social benefits of the trade. Disease ecologists and public health experts

provide important scientific insights on pathogen transmission through the exotic pet trade and actions that would reduce the risk of pathogen transmission to native species, domesticated animals, and humans. Social scientists provide insights into human behavior, motivations, and decision-making processes (Bennett et al. 2017), and can assist in navigating transdisciplinary collaboration (Marchini et al. 2021). Specialists in strategic communication offer valuable insights into effective messaging and conflict resolution strategies (Gregg et al. 2022). Strategic communication ensures that decisions are communicated clearly, the rationale for decisions is understood, and buy-in is obtained from relevant parties, thereby fostering collaboration in the implementation of decisions and reducing misconceptions (Werder 2014). Involving legal experts in decision-making ensures that policies and regulations are legally sound and comply with existing laws and regulations (Schwarz 2008; McEl-downey et al. 2013), and reduces loopholes and opportunities for non-compliance.

Addressing the wicked problem of the exotic pet trade requires collaborative engagement between different scientific disciplines, government agencies, and key stakeholders in the exotic pet trade to identify management actions. This is an extremely challenging task that requires scientists and managers to pivot from current conventional scientific and management models to embrace uncertainty and complexity. We recognize that SDM requires time, effort, and active engagement by different government agencies, an array of different scientific disciplines, and the exotic pet trade. However, collaborative, multidisciplinary management can generate shared understanding between stakeholders that facilitate innovative, adaptive problem-solving, particularly in addressing wicked problems where complexity and uncertainty of management arise (Stout et al. 1999; Lauber et al. 2011). SDM has been used to address conflicts related to game species harvests (Robinson et al. 2016), wildlife disease management (McEachran et al. 2024), and species invasions (Pepin et al. 2022). Reframing management of the exotic pet trade with decision analysis can re-establish trust in scientists and managers by accounting for diverse and competing interests and world views, the consequences of policy actions, and power dynamics related to the exotic pet trade (Rittel and Webber 1973; Game et al. 2014; Mason et al. 2018).

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

This study involved human subjects research in the form of online surveys. Our study was reviewed and approved by the appropriate Human Research Ethics Committee. The Institutional Review Board at the University of Georgia reviewed the final survey and determined it was exempt (ID: PROJECT00006638).

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Author contributions

Pratt: Conceptualization, data curation, formal analysis, investigation, methodology, visualization, writing - original draft. Lockwood: Methodology, visualization, writing - review and editing. King: Methodology, visualization, writing - review and editing. Pienaar: Conceptualization, investigation, methodology, supervision, visualization, writing - original draft, writing - review and editing.

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Data availability

The data underpinning the analysis reported in this paper are deposited at Zenodo, and are available at <https://doi.org/10.5281/zenodo.14802808>.

References

- Adams LB, Alter TR, Parkes MW, Reid M, Woolnough AP (2019) Political economics, collective action and wicked socio-ecological problems: A practice story from the field. *Gateways : International Journal of Community Research & Engagement* 12(1): 6342. <https://doi.org/10.5130/ijcre.v12i1.6496>
- Auliya M, Altherr S, Ariano-Sanchez D, Baard EH, Brown C, Brown RM, Cantu J, Gentile G, Gildenhuys P, Henningheim E, Hintzmann J, Kanari K, Krvavac M, Lettink M, Lippert J, Luiselli L, Nilson G, Nguyen TQ, Nijman V, Parham JF, Pasachnik SA, Pedrono M, Rauhaus A, Rueda Córdova D, Sanchez M, Schepp U, van Schingen M, Schneeweiss N, Segniagbeto GH, Somaweera R, Sy EY, Türkozan O, Vinke S, Vinke T, Vyas R, Williamson S, Ziegler T (2016a) Trade in live reptiles, its impact on wild populations, and the role of the European market. *Biological Conservation* 204: 103–119. <https://doi.org/10.1016/j.biocon.2016.05.017>
- Auliya M, García-Moreno J, Schmidt BR, Schmeller DS, Hoogmoed MS, Fisher MC, Pasmans F, Henle K, Bickford D, Martel A (2016b) The global amphibian trade flows through Europe: The need for enforcing and improving legislation. *Biodiversity and Conservation* 25(13): 2581–2595. <https://doi.org/10.1007/s10531-016-1193-8>
- Baker SE, Cain R, van Kesteren F, Zommers ZA, D’Cruze N, Macdonald DW (2013) Rough trade: Animal welfare in the global wildlife trade. *Bioscience* 63(12): 928–938. <https://doi.org/10.1525/bio.2013.63.12.6>
- Bammer G (2005) Integration and implementation sciences: Building a new specialization. *Ecology and Society* 10(2): 6. <https://doi.org/10.5751/ES-01360-100206>
- Bennett NJ, Roth R, Klain SC, Chan K, Christie P, Clark DA, Cullman G, Curran D, Durbin TJ, Epstein G, Greenberg A, Nelson MP, Sandlos J, Stedman R, Teel TL, Thomas R, Veríssimo D, Wyborn C (2017) Conservation social science: Understanding and integrating human dimensions to improve conservation. *Biological Conservation* 205: 93–108. <https://doi.org/10.1016/j.biocon.2016.10.006>
- Bertuol-Garcia D, Morsello C, El-Hani CN, Pardini R (2018) A conceptual framework for understanding the perspectives on the causes of the science–practice gap in ecology and conservation. *Biological Reviews of the Cambridge Philosophical Society* 93: 1032–1055. <https://doi.org/10.1111/brv.12385>
- Bowen H (2021) An analysis of the effectiveness of law and policy in assisting in control and prevention of non-native invasive species spread in England and Wales. Masters Thesis. Bournemouth University (Poole).
- Brown R (2006) Exotic pets invade United States ecosystems: Legislative failure and a proposed solution. *Indiana Law Journal* 81: 713–731.
- Burgos-Rodríguez J, Burgiel SW (2020) Federal legal authorities for the early detection of and rapid response to invasive species. *Biological Invasions* 22: 129–146. <https://doi.org/10.1007/s10530-019-02148-w>
- Bush ER, Baker SE, Macdonald DW (2014) Global trade in exotic pets 2006–2012. *Conservation Biology* 28(3): 663–676. <https://doi.org/10.1111/cobi.12240>

- Can ÖE, D'Cruze N, Macdonald DW (2019) Dealing in deadly pathogens: Taking stock of the legal trade in live wildlife and potential risks to human health. *Global Ecology and Conservation* 17: e00515. <https://doi.org/10.1016/j.gecco.2018.e00515>
- Cook JD, Campbell Grant EH, Ginsberg HS, Prosser DJ, Runge MC (2025) Enhancing One Health outcomes using decision science and negotiation. *Frontiers in Ecology and the Environment* 2827: e2827. <https://doi.org/10.1002/fee.2827>
- Cosens BA, Ruhl JB, Soininen N, Gunderson L (2020) Designing law to enable adaptive governance of modern wicked problems. *Vanderbilt Law Review* 73: 1687–1732.
- de Vos CJ, Swanenburg M, Tafro N, van Roon A, Stenvers OFJ, Elbers ARW (2017) Animal health risk of legally imported exotic animals into the Netherlands in the period 2013–2014. *Microbial Risk Analysis* 6: 9–20. <https://doi.org/10.1016/j.mran.2017.05.002>
- Episcopio-Sturgeon DJ, Pienaar EF (2019) Understanding stakeholders' opinions and preferences for non-native pet trade management in Florida. *Human Dimensions of Wildlife* 24(1): 46–60. <https://doi.org/10.1080/10871209.2019.1537016>
- Fonseca É, Zank C, Cechin SZ, Both C (2021) Reptile pet trade in Brazil: A regulatory approach to sustainable biodiversity conservation. *Conservation Science and Practice* 3(10): e504. <https://doi.org/10.1111/csp2.504>
- Game ET, Meijaard E, Sheil D, McDonald-Madden E (2014) Conservation in a wicked complex world; Challenges and solutions. *Conservation Letters* 7(3): 271–277. <https://doi.org/10.1111/conl.12050>
- Gippet JMW, Bertelsmeier C (2021) Invasiveness is linked to greater commercial success in the global pet trade. *Proceedings of the National Academy of Sciences of the United States of America* 118(14): e2016337118. <https://doi.org/10.1073/pnas.2016337118> [PNAS]
- Gregg EA, Kidd LR, Bekessy SA, Martin JK, Robinson JA, Garrard GE (2022) Ethical considerations for conservation messaging research and practice. *People and Nature* 4(5): 1098–1112. <https://doi.org/10.1002/pan3.10373>
- Harris J, Brown VA, Russell J (2010) Tackling wicked problems: Through the transdisciplinary imagination. Earthscan, London/New York, 1–312.
- Hausmann A, Cortés-Capano G, Fraser I, Di Minin E (2023) Assessing preferences and motivations for owning exotic pets: Care matters. *Biological Conservation* 281: 110007. <https://doi.org/10.1016/j.biocon.2023.110007>
- Hulme PE (2015) Invasion pathways at a crossroad: Policy and research challenges for managing alien species introductions. *Journal of Applied Ecology* 52(6): 1418–1424. <https://doi.org/10.1111/1365-2664.12470>
- Lauber TB, Stedman RC, Decker DJ, Knuth BA (2011) Linking knowledge to action in collaborative conservation. *Conservation Biology* 25(6): 1186–1194. <https://doi.org/10.1111/j.1523-1739.2011.01742.x>
- Levin K, Cashore B, Bernstein S, Auld G (2012) Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences* 45(2): 123–152. <https://doi.org/10.1007/s11077-012-9151-0>
- Lockwood JL, Welbourne DJ, Romagosa CM, Cassey P, Mandrak NE, Strecker A, Leung B, Stringham OC, Udell B, Episcopio-Sturgeon DJ, Tlustý MF, Sinclair J, Springborn MR, Pienaar EF, Rhyne AL, Keller R (2019) When pets become pests: The role of the exotic pet trade in producing invasive vertebrate animals. *Frontiers in Ecology and the Environment* 17(6): 323–330. <https://doi.org/10.1002/fee.2059>
- Marchini S, Ferraz KMPMB, Foster V, Reginato T, Kotz A, Barros Y, Zimmermann A, Macdonald DW (2021) Planning for human-wildlife coexistence: Conceptual framework, workshop process, and a model for transdisciplinary collaboration. *Frontiers in Conservation Science* 2: 752953. <https://doi.org/10.3389/fcsc.2021.752953>

- Marra PP (2019) The ecological cost of pets. *Current Biology* 29(19): R955–R956. <https://doi.org/10.1016/j.cub.2019.06.067>
- Mason THE, Pollard CRJ, Chimalakonda D, Guerrero AM, Kerr-Smith C, Milheiras SAG, Roberts M, Ngafack PR, Bunnefeld N (2018) Wicked conflict: Using wicked problem thinking for holistic management of conservation conflict. *Conservation Letters* 11: e12460. <https://doi.org/10.1111/conl.12460>
- McEachran MC, Harvey JA, Mummah RO, Bletz MC, Teitelbaum CS, Rosenblatt E, Rudolph FJ, Arce F, Yin S, Prosser DJ, Mosher BA, Mullinax JM, DiRenzo GV, Couret J, Runge MC, Campbell Grant EH, Cook JD (2024) Reframing wildlife disease management problems with decision analysis. *Conservation Biology* 38(4): e14284. <https://doi.org/10.1111/cobi.14284>
- McEldowney J, Grant W, Medley G (2013) The regulation of animal health and welfare: Science, law and policy. Routledge, London, 1–200. <https://doi.org/10.4324/9780203522608>
- Mitroff II, Silvers A (2010) Dirty rotten strategies: How we trick ourselves and others into solving the wrong problems precisely. Stanford University Press, Stanford, 1–210. <https://doi.org/10.1515/9781503627260>
- Oppenheimer M (2011) What roles can scientists play in public discourse? *Eos* 92(16): 133–134. <https://doi.org/10.1029/2011EO160001>
- Pasmans F, Bogaerts S, Braeckman J, Cunningham AA, Hellebuyck T, Griffiths RA, Sparreboom M, Schmidt BR, Martel A (2017) Future of keeping pet reptiles and amphibians: Towards integrating animal welfare, human health and environmental sustainability. *The Veterinary Record* 181(17): 450. <https://doi.org/10.1136/vr.104296>
- Pepin KM, Davis AJ, Epanchin-Niell RS, Gormley AM, Moore JL, Smyser TJ, Shaffer HB, Kendall WL, Shea K, Runge MC, McKee S (2022) Optimizing management of invasions in an uncertain world using dynamic spatial models. *Ecological Applications* 32(6): e2628. <https://doi.org/10.1002/eap.2628>
- Pienaar EF, Sturgeon DJE (2024) Exotic pet owners' preferences for different ectothermic taxa are based on species traits and purchase prices in the United States. *NeoBiota* 91: 1–27. <https://doi.org/10.3897/neobiota.91.109403>
- Pratt EN, Lockwood JL, King EG, Pienaar EF (2024) Identifying inconsistencies in exotic pet regulations that perpetuate trade in risky species. *Conservation Biology* 38(2): e14189. <https://doi.org/10.1111/cobi.14189>
- Reeve R (2006) Wildlife trade, sanctions and compliance: Lessons from the CITES regime. *International Affairs* 82(5): 881–897. <https://doi.org/10.1111/j.1468-2346.2006.00576.x>
- Rhyne AL, Tlusty MF, Schofield PJ, Kaufman L, Morris JA, Bruckner AW (2012) Revealing the appetite of the marine aquarium fish trade: The volume and biodiversity of fish imported into the United States. *PLoS ONE* 7(5): e35808. <https://doi.org/10.1371/journal.pone.0035808>
- Rittel HWJ, Webber MM (1973) Dilemmas in a general theory of planning. *Policy Sciences* 4(2): 155–169. <https://doi.org/10.1007/BF01405730>
- Robinson JE, Griffiths RA, St. John FAV, Roberts DL (2015) Dynamics of the global trade in live reptiles: Shifting trends in production and consequences for sustainability. *Biological Conservation* 184: 42–50. <https://doi.org/10.1016/j.biocon.2014.12.019>
- Robinson KF, Fuller AK, Hurst JE, Swift BL, Kirsch A, Farquhar J, Decker DJ, Siemer WF (2016) Structured decision making as a framework for large-scale wildlife harvest management decisions. *Ecosphere* 7(12): e01613. <https://doi.org/10.1002/ecs2.1613>
- Runge MC, Converse SJ, Lyons JE, Smith DR (2020) Structured decision making: Case studies in natural resource management. Johns Hopkins University Press, Baltimore, 1–272.
- Schwarz FAO (2008) Lawyers for government have unique responsibilities and opportunities to influence public policy. *New York Law School Law Review*. New York Law School 53: 375–407.

- Sinclair JS, Stringham OC, Udell B, Mandrak NE, Leung B, Romagosa CM, Lockwood JL (2021) The international vertebrate pet trade network and insights from US imports of exotic pets. *Bio-science* 71(9): 977–990. <https://doi.org/10.1093/biosci/biab056>
- Smith KM, Smith KF, D’Auria JP (2012) Exotic pets: Health and safety issues for children and parents. *Journal of Pediatric Health Care* 26(2): E2–E6. <https://doi.org/10.1016/j.pedhc.2011.11.009>
- Stern MJ, Coleman KJ (2015) The multidimensionality of trust: Applications in collaborative natural resource management. *Society & Natural Resources* 28(2): 117–132. <https://doi.org/10.1080/08941920.2014.945062>
- Stout RJ, Cannon-Bowers JA, Salas E, Milanovich DM (1999) Planning, shared mental models, and coordinated performance: An empirical link is established. *Human Factors* 41(1): 61–71. <https://doi.org/10.1518/001872099779577273>
- Stringham OC, García-Díaz P, Toomes A, Mitchell L, Ross JV, Cassey P (2021) Live reptile smuggling is predicted by trends in the legal exotic pet trade. *Conservation Letters* 14(6): e12833. <https://doi.org/10.1111/conl.12833>
- Sutherland M, Baron H, Llinas J (2021) Recommended health care and disease-prevention programs for herds/flocks of exotic animals. *The Veterinary Clinics of North America. Exotic Animal Practice* 24(3): 697–737. <https://doi.org/10.1016/j.cvex.2021.05.003>
- Toland E, Bando M, Hamers M, Cadenas V, Laidlaw R, Martínez-Silvestre A, van der Wielen P (2020) Turning negatives into positives for pet trading and keeping: A review of positive lists. *Animals* 10(12): 2371. <https://doi.org/10.3390/ani10122371>
- van Roon A, Maas M, Toale D, Tafro N, van der Giessen J (2019) Live exotic animals legally and illegally imported via the main Dutch airport and considerations for public health. *PLoS ONE* 14(7): e0220122. <https://doi.org/10.1371/journal.pone.0220122>
- Waddock S, Lozano JM (2013) Developing more holistic management education: Lessons learned from two programs. *Academy of Management Learning & Education* 12(2): 265–284. <https://doi.org/10.5465/amle.2012.0002>
- Warwick C, Steedman C, Toland E (2016) Welfare of exotic pets. *The Veterinary Record* 178(25): 640. <https://doi.org/10.1136/vr.i3350>
- Warwick C, Steedman C, Jessop M, Arena P, Pilny A, Nicholas E (2018) Exotic pet suitability: Understanding some problems and using a labeling system to aid animal welfare, environment, and consumer protection. *Journal of Veterinary Behavior* 26: 17–26. <https://doi.org/10.1016/j.jveb.2018.03.015>
- Werder KP (2014) A theoretical framework for strategic communication messaging. In: Holtzhausen D, Zerfass A (Eds) *The Routledge handbook of strategic communication*. Routledge, New York, 269–284.
- Whitehead ML (2016) Welfare of exotic pets. *The Veterinary Record* 178(19): 477. <https://doi.org/10.1136/vr.i2517>

Supplementary material 1

Additional results for reference by readers and the reviewers

Authors: Elizabeth N. Pratt, Julie L. Lockwood, Elizabeth G. King, Elizabeth F. Pienaar

Data type: docx

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